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SOCIETAL LIFE CYCLE ASSESSMENT

Social impact assessment in LCA using the Preston pathway

The case of banana industry in Cameroon

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Abstract
Purpose The purpose of the social Life Cycle Assessment (LCA) method is to predict the social impacts on people caused by the changes in the functioning of one product chain throughout its life cycle. Changes in health status are very important experiences for people. The aim of this paper is to build a pathway between changes in economic activity generated by the functioning of a product chain and the changes in health status of the population in the country where the economic activity takes place.

Methods Empirical and historical factors suggest that increased economic activity through growth in income leads to improvements in the health of a country's population. This empirical relationship is well known in economics as the Preston curve. Using this relationship, we design a pathway for social LCA impact assessment. This pathway may be used to explain or predict the potential impact caused by the modification of one product sector upon the health of a population. The Preston relationship usually is calculated for a cross section of countries. We assess whether the Preston relationship is valid when a single country is considered alone. Drawing from scientific literature regarding development, we define the *context* where the use of the Preston relationship is justified. We describe the general design of the Preston pathway, using a recalculated (panel based) relationship, and specify the conditions for its use. We apply it to the case of company B, a banana industry in Cameroon, for the period between 2010 and 2030.

Results We highlight that the panel calculation of the Preston relationship remains significant when a country is considered alone. We suggest that the following conditions are required for the pathway to be used: (1) the activity is set within countries where the GDP per capita in purchasing power parity is less than $10,000 at the start of the period, (2) the assessed activity accounts for a significant part of the annual GDP and/or demonstrates obvious signs that it represents a huge stake in the country's economy, (3) the duration of the assessed activity is regular and long enough, and (4) the added value created by the activity is shared within the country. We found that the future activity of company B would improve the potential LEX of the entire population of Cameroon by 5 days over 20 years, based on 200,000 t of bananas exported annually (in comparison with no activity).

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Conclusions When the four conditions for use are met, and provided results are interpreted by comparing them with other situations or countries, the recalculated panel-based relationship may be used to explain or predict a change in potential life expectancy generated by a change in economic activity. The Preston pathway may be useful for impact assessment in social LCA. The assessment is valid only when used for a comparative analysis and must be done within a multi-criteria framework. Complementary pathways therefore need to be designed. We suggest that the conditions for use and other research issues be discussed and fine-tuned further. Moreover, we welcome comments and criticisms.

Keywords Banana · Cameroon · Health · Pathway · Preston curve · Social LCA

1 Introduction

The purpose of the social Life Cycle Assessment (LCA) method is to predict the social impacts on people caused by changes in the functioning of one product chain throughout its life cycle. To do so, an operational relationship must be established between a level of criteria that is easy to handle and the level of the assessed impact. "Pathway" is the name conventionally used to refer to this operational relationship and the conditions under which it may be applied (Parent et al. 2010). One impact of particular interest is change in people's health status. Of course, health status is only a part of the area of protection "human well-being". Improvement of well-being is the real purpose of actions taken on the basis of LCA studies (Jørgensen et al. 2012). Nevertheless, in this paper we consider only the impact "human health" and suggest only one pathway to assess changes in health. Other pathways could lead to others changes in life expectancy; they will be addressed in future papers.

There is strong empirical and historical evidence suggesting that increased economic activity leads to improvements in the health of a population. This relationship was first proposed by the American demographer Samuel Preston (1975). He developed the "Preston curve", which links life expectancy at birth, a proxy for health, with income per capita at a given time, a proxy for wealth. In some countries, a significant portion of total wealth is generated by a single product sector (i.e. some high-value crops, high technology). If growing economic activity has an effect on population health, and if one economic sector plays a dominant role in this economic activity, then we hypothesize that the sector contributes to improving the health of the population. It improves the health of the population by generating local added value (see Section 3.2 for the explanation of the calculation of the local added value). Provided that certain conditions are fulfilled, it is possible to explain and predict past and future effects on the health of a population by studying long-term changes in such a product sector.

We share the most epidemiologists' position that socioeconomic determinants of population health status depend first on the absolute level of income available to one person (this is called the "absolute income hypothesis"). Second, it depends on his/her level of income compared to the rest of the population (this is called the "relative income hypothesis"). In this first paper, we only deal with the absolute income hypothesis. Further work is underway to develop other pathways taking into account the relative income hypothesis. Of course, social spending, and especially in health care, is an important issue to improve population health. Starting from our hypothesis, social spending in health care appears as a secondary variable whose level is determined by the national absolute income and by the income distribution in the population. That is why we do not consider the level of social spending in itself in this paper.

The purpose of this paper is to build a "Preston pathway" for use in social LCA. In Section 1, we present the scientific basis of the Preston curve. We discuss how to design the Preston pathway for social LCA in Section 3. Section 4 presents a case study of the banana industry in Cameroon accounting for the implementation of the Preston pathway only.

2 Scientific basis of the pathway: the Preston curve

The Preston curve is an empirical cross-section relationship between real life expectancy at birth (LEX) and real per capita income (GDP[1]). Preston (1975) tested the relationship for the 1900s, 1930s and the 1960s.

2.1 What is the Preston curve?

2.1.1 Life expectancy as a proxy for health

Health was recognized as an essential component of human development in many development reports published in the 1990s (UNDP 1990; United Nations 2000; World Bank 2001). Today, health is a central non-monetary variable of the Human Development Index. However, although there is a general consensus that health is an important component of human development, there is less agreement as to how it should be evaluated. Conceptually, the evaluation of health should take into account morbidity and mortality. Practically, it should consider data on mortality as well as on disease

[1] Later in the paper this abbreviation will be used to refer to GDP per capita. We never use the global GDP.

prevalence and the frequency of each type of disability associated with each disease. Canning (2010) demonstrated a strong correlation between LEX and healthy life expectancy, or the number of years that may be lived in good health, based on data from 192 countries collected in 2002. Consequently, LEX is a fairly good proxy for health when other data are lacking especially data on quality of life (Canning 2010).

2.1.2 GDP as a proxy for real income

Within a given country, it is impossible to determine an individual's overall income. The gross domestic product divided by the number of people in the country therefore often is used as an approximation. Expressing gross domestic product at "Purchasing Power Parity" (PPP) provides a means to compare countries that are not affected by the following: a) abrupt and sudden changes in currency exchange rates, b) sub-currency assessments, and c) arbitrary fixed exchange rates. Preston (2007) justifies the use of gross domestic product per capita when assessing health.

2.1.3 Presentation of the relationship

Preston (1975) sets in relationship the GDP and LEX for a cross section of countries (1) at one point in time. The basic empirical relationship may be expressed by the following Eq. (1):

$$\forall_i, \ln(\mathrm{LEX}_i) = \alpha + \beta \ln(GDP_i) + \varepsilon_i \quad (1)$$

Where:

$\ln(\mathrm{LEX}_i)$	is the natural logarithm of the life expectancy at birth for the country i
$\ln(\mathrm{GDP}_i)$	is the natural logarithm of GDP per capita (PPP) for the country i
ε_i	is the error term with standard errors clustered at country level
α	is a constant, and
β	is the coefficient of regression on income (called elasticity in Economics).

The Preston curve for the year 2009 is presented in Fig. 1. Deaton (2007) provides a dynamic reading of the curve: "On the left of the graph, among the poorest countries, small changes in income are associated with large increases in life expectancy. These are the countries that are yet to experience the 'epidemiological transition', during which infectious diseases, which mostly kill children, give way to chronic diseases, such as cancers and heart diseases, which mostly kill elderly people. Among the rich countries, on the right of the graph and which are beyond the transition, increases in income are associated with smaller, but still positive, increases in life expectancy."

Many questions nevertheless remain regarding the relationship between income, represented by GDP, and health, represented by LEX. For example, what is the causal direction—from income to health or the reverse? Does GDP matter as much as is widely believed? May the relationship between GDP and LEX be applied to a single country and can it be used for predictive purposes?

2.2 Features of the Preston curve

2.2.1 Direction of the relationship

Does wealth improve LEX or does LEX contribute to wealth? Some economics authors doubt that there is a causal link running from income to health, arguing that the relationship runs in the opposite direction (Deaton 2003). The reverse relationship, from health to income, has been fully investigated (Bloom and Canning 2007). Healthier workers are more productive, and longer life spans create incentives to invest in schooling and save for retirement (Bloom and Canning 2000); healthier children are likely to attend school more regularly (Alderman et al. 2001), and more easily absorb knowledge while in school, and increase their cognitive ability (Dickson et al. 2000). However, although numerous studies have attested to the existence of an effect from LEX towards wealth, the magnitude of the relationship is so weak that "the effects of health on socioeconomic status [−] are negligible" (Deaton 2002, p. 16). Paradoxically, studies that take into account the two effects lead to a reinforcement of the Preston relationship (Pritchett and Summers 1996; Filmer and Pritchett 1999). This confirms that the main effect goes from income toward health (Pritchett and Viarengo 2010).

2.2.2 Is GDP the key factor for health?

The effect of income on health is open to question. Several factors affect health, and interactions between these factors render a precise accounting difficult (Canning 2010). Two opposing views may be found in scientific literature (Kenny 2009). The first maintains that increases in income are central to the process of mortality transition (Pritchett and Summers 1996; Fogel 2004). The second (Hanmer et al. 2003; Deaton and Paxson 2004) questions the central importance of greater income in achieving health improvements (Kenny 2009). Nevertheless, a *historical perspective* supports the idea that increases in income improve health. Bloom and Canning (2000) demonstrated that *before 1870, the health of populations in rich and poor countries were very similar* (LEX was less than 40 years). After 1870, health improved in

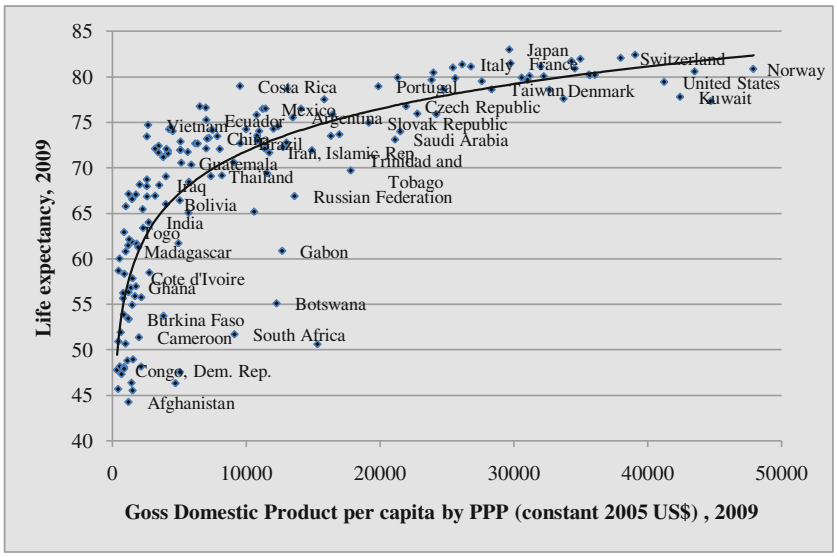

Fig. 1 The Preston curve for 2009

Source: Data from Gapminder (2009)

newly rich countries whereas improvements in poor countries started only after 1930, when their GDP began to rise (p. 498). Recently, two epidemiologists wrote, "It is now almost universally accepted amongst scholars and practitioners of public health that the most important determinants of health are social and economic circumstances" (Wilkinson and Pickett 2010, p. 277).

2.2.3 Is the relationship between GDP and health right for one given country?

The Preston relationship usually is calculated by cross-sectional analysis. This method does not deliver a dynamic approach to the individual behaviour of each country (Sevestre 2002), but it does depict the situation for the world as a whole at a given time. However, as suggested by Pritchett and Viarengo (2010), it is possible that the cross-sectional relationship does not represent the expected trajectory of a specific country experiencing growth in income.

We performed our own calculations with panel data to determine the relationship (2) between LEX_t and GDP_t whatever the country. The relationship (2) is an *approximation* of the real relationship. Its obvious interest is to be a linear relationship linking Ln(LEX) and Ln(GDP). Nevertheless, its domain of validity is limited for prediction, as we will discuss in Section 3.3.1. This method allows dynamic behaviour (the varying situation of individual entities over time) and heterogeneity between individual entities to be taken into account (Sevestre 2002). This method also can reflect the influence of unobservable characteristics of individual entities as long as they remain stable over time. We used the panel of 107 countries for which we got all the data. We eliminated countries with high HIV prevalence rate. It covers a wide diversity of situations in terms of economic development and geographical location, from 1950 to 2009. All the details and the results of the econometric analysis are presented in the supplementary material. The resulting relationship (2) delivers a high quality of adjustment.

$$\forall\, i \in [1,N], \forall\, t \in [1,T], \ln(\mathrm{LEX}_{it}) = 2.6432 + 0.1745\ \ln(\mathrm{GDP}_{it}) + \varepsilon_{it},\ R^2 = 0.80 \qquad (2)$$

Where

$\ln(\mathrm{LEX}_{it})$	is the natural logarithm of the life expectancy at birth for the country i at the time t
$\ln(\mathrm{GDP}_{it})$	is the natural logarithm of GDP per capita (PPP) for the country i at the time t; and
ε_{it}	is the error term.

We confirmed the validity of the relationship for a given country over time. This result was also obtained by Pritchett and Viarengo (2010) from a time series analysis. This means that the recalculated relationship is relevant for one country considered alone.

2.2.4 Can we use the Preston relationship for predictive purposes by country?

There is a temptation to extrapolate the Preston curve to predict the future, assuming that economic growth improves health, as claimed by Pritchett and Summers (1996): "Using instrumental variables estimation and data across countries and over time, we find strong evidence that the positive relationship between income and health is *not merely associative but is causal and structural*" (p. 844).

The predictive link is well documented for poor countries (Case 2001, 2002; Deaton 2007; Klugman

2010). Rising incomes lead to improved health through an increase in private and public expenditures (Pritchett and Summers 1996). The epidemiologists Wilkinson and Pickett (2010) comment: "For rich countries, to get richer adds nothing further to their life expectancy" (p. 6). They point out, however, that "In poorer countries, economic development continues to be very important for human wellbeing [−] but as nations join the ranks of the affluent developed countries, further rises in income count for less and less." (p. 8). Pritchett and Viarengo (2010) agree, noting: "In whatever functional form, per capita income has a strong and statistically robust association with life expectancy, especially over the range up to GDP per capita in PPP of $10,000" (p. 2). Pritchett and Summers (1996) calculate that "if income were one percent higher in the developing countries, up to 33,000 infant and 53,000 child deaths would be averted annually" (p. 844). Citing Canning (2010), they argue that "focusing on economic growth in developing countries will lead directly to reductions in infant mortality rates and improvements in life expectancy, as they see improved health as a by-product of higher income levels".

Nevertheless, the high correlations are more between income and health *levels* than between *changes* (Klugman 2010, p. 47) and especially for small changes. The causes are double. First, the real Preston relationship is not linear. Second, there is a *time lag* between an observed increase in income and health effects. Easterly (1999) refers to the length and variability of time required for growth to lead to changes in quality of life (p. 267); he suggests that a period of 10 years is insufficient, and stresses that growth in private income does not necessarily entail progress in public goods.

To be able to predict an improvement in life expectancy, the economic activity must take place over a sufficiently long period. When short time horizons are used, or during a period of stagnation or sharp fluctuations in national income per capita, the prediction does not work.

3 Using the Preston pathway in social LCA

Social LCA researchers call for the development of pathways. While the UNEP/SETAC guidelines (2009) regret that, "cause–effect relationships are not simple enough or not known with enough precision to allow quantitative cause–effect modeling", Weidema (2006) proposes six categories[2] of impacts and suggests relationships to calculate changes. Jørgensen et al. (2010a) suggest a pathway linking unemployment and several social impacts. The same team (Jørgensen et al. 2010b) proves that it is possible to assess the validity of impact pathways, and regrets that sufficient research has not been devoted to developing them. We propose to build the "Preston pathway" from the recalculated relationship (2) to be used in impact assessment for social LCA.

3.1 Background

Early works in LCA have used impact pathways (Norris 2006; Hutchins and Sutherland 2008) characterizing certain health effects resulting from changes in economic activity. Hutchins and Sutherland (2008) examine the relationship between infant mortality and GDP per capita and measure the effect of changing one supplier (from a different country). Norris (2006) uses World Bank data from 2002 to reconstruct the Preston curve. He analysed the regional distribution of the economic activity in the supply chain of Dutch electricity. The author highlighted that while only 10 % of the total economic activity was generated in non-Organisation for Economic Co-operation and Development (OEDC) countries, the health benefits in the non-OECD countries dwarf the health benefit and cost impacts in the OECD regions. However, both of these works acknowledge that the limitation of the impact pathway method is that the local context is not taken into consideration. They also both highlight crucial issues (for instance sharing of growth benefits within the country) which will be discussed below.

3.2 General design for the Preston pathway

The Preston pathway is designed to assess one part of one social impact (changes in health) of a given life cycle. We hypothesize that one part of this life cycle is performed by entity B[3] which is monoproduct and established in a given country A. We want to calculate the impact caused by the activity of entity B in country A on the LEX of the population. The idea is to use the relationship (2) to calculate past or future LEX in country A under a growth hypothesis and starting from real LEX. For prediction, the result is: "under such conditions, such a growth would entail such a change in LEX". Entity B contributes to that growth thanks to its "local added value". Local added value of entity B is all the added value which is really created by entity B and injected into, and thus shared within, the local economy. It is not only the value directly provided to entity B stakeholders (employees, local suppliers, the

[2] Longevity, non-fatal impacts on human health, autonomy, safety security and tranquillity, equal opportunity, participation and influence.

[3] Entity B may be one company, or several small craft workshops, or farms, etc.

government…) but also that generated by these stakeholders themselves through their spending in the local economy (domino effect). The different components of the local added value and their relationships with different affected actors are highlighted in Table 1. The calculation of the local added value of entity B requires access to the accounting records of entity B and to the detailed national accounts of country A. GDP is the sum of the added values created by all of the economic agents in the country. We assume that entity B does contribute to the increase in LEX at the exact rate of its contribution to national gross domestic product (which is the rate between its local added value and national gross domestic product). An example is given in Section 4.

Within this general design, several issues are still pending which will be discussed later in the article. One, however, must be noted immediately: the LEX that is calculated is a potential figure, as is the case for environmental LCA impacts, due to spatial and temporal variability and uncertainties. The Preston curve stands for an empirical relationship between *real* GDP per capita and *real* LEX, as far as they can be measured. When the relationship (2) is used for social LCA, the starting point of the simulation is *real* (real GDP per capita and real LEX), but the calculation is made based on a *hypothesis*. The calculated LEX is therefore a *potential* figure. It is the LEX which may arise if the country follows the exact same trajectory as other countries in the past. It is the trajectory designed by the relationship (2)—which is based on an assumption that everything else in the world is held constant with the exception of this hypothetical growth in a country's GDP. Of course, this assumption never holds true in real life. It consequently is meaningless to interpret a potential LEX alone without comparing it to other countries' results.

3.3 Uncertainties and proposed conditions for use of the Preston pathway

Within LCA models, uncertainties stem from two sources; (1) variability and lack of precision in the underlying data, and (2) bias introduced by a lack of accuracy of the model (Schmidt and Weidema 2009). All of these uncertainties could lead to large errors when calculating a potential

Table 1 Components of the local value added and relationships with affected actors

Local value added=	Direct primary value added[a]	+ Indirect primary value added	+ Direct and indirect secondary added value
Source documents	Company balance sheet	National accounts (42 sectors)	Profile of household consumption+ national accounts (42 sectors)
Actor conveying the effect	Company's employees, State, external services	Local business partners/suppliers, State	Households, State
Composition	✔ Employees' compensation (wages and payroll) (6.4)[c]	✔ VA generated through local intermediate consumption/ inputs with local suppliers	✔ VA generated through households consumption in local economy
	✔ Employees' additional costs (housing, transport, etc.) (6.4)	- EBITDA[b]	- EBITDA
	✔ Inventory changes (6.03)	- Wages	- Wages
	✔ Taxes (6.3)	- Marketing margins	- Marketing margins
	✔ Financial expenses (6.6)	- Taxes	- Taxes
	✔ Depreciation (6.8)	- Custom taxes	- Custom taxes
	✔ Insurance (6.16)	- Inventory changes	- Inventory changes
	✔ Subsides (7.4)	✔ Taxes (custom taxes and special taxes) and marketing margins on imported inputs of the company	✔ Payroll taxes on induced wages
			✔ Personal income tax of the company's employees and induced employees generated by the consumption of the company's employees
			✔ VAT on final consumption

[a] The calculation of the direct primary value added is different from the calculation of the accounting value added. It refers to the definition used in the national accounts. The difference between both calculations stems from different allocations of the items

[b] Earnings before interest taxes depreciation and amortization

[c] Numbers in parentheses refer to classes of French Accounting Plan (private accounts) where one can find the different items

LEX result. They are so numerous that we could face the situation denounced by Lenzen (2006), where "the uncertainty of these factors causes the uncertainty of subsequent impact measures to increase. Eventually, the high degree of overlap of the bell-shaped value distributions precludes decision-making" (p. 190). In response to this situation, we can do little about variability or lack of precision, but we can take care to apply the method as accurately as possible. The main issue is about the non-linearity of the Preston relationship. The non-linearity is highlighted by the fact that the relationship does not hold in variations (relationship between changes in GDP/capita and changes in LEX is weak) despite it holds strongly in level. The non-linearity consequence is that we cannot implement *directly* any approximation of the real relationship (built from macro economic variables), in order to predict micro economic phenomena. For this purpose, we must respect *two rules*: a) the linear relationship (which is an approximation of the real relationship) only may be used when the context of the country and the sector complies with the required conditions described below. Under these conditions, the approximation of the real relationship by the linear relationship (2) is fair, and so conditions for downscaling from macro- to micro-level are met; b) potential LEX results are interpreted only through a comparative analysis, both calculations being carried out with the same variables and the same methodology, and within a multi-criteria framework.

The conditions for use described below meet the first rule. The second rule regarding how to analyse LEX results will be dealt with in Section 5.

3.3.1 Condition 1: national income

Given the preceding discussion, the relationship (2) will be applied only to the parts of the assessed life cycle which are located in poor countries, with a gross domestic product per capita PPP of less than $10,000 (Pritchett and Viarengo 2010), which is approximately equivalent to that of Mexico. Indeed, the non-linear real relationship is reasonably well approximated by the double natural log specification, but only until the value of $10,000. Pritchett and Viarengo (2010) compared the linear approximation with the quadratic form, which *better accounts for the reality* of the phenomena. They looked at the value of the unique elasticity (β) of the double natural log relationship, in comparison with the four elasticities ($\beta 1$ to $\beta 4$) provided by the quadratic form, allowing for up to a fourth power in GDP/capita. They made the calculations for all available data, each 5 years, for one century, and for different levels of GDP/capita. They found that the approximation of the quadratic form by the double natural log–log relationship was correct between $1,250 and $10,000, but not fair for richer countries (Pritchett and Viarengo 2010, p. 21).

Average health state in rich countries also is sensitive to the level of GDP/capita, but the relationship (2) is not a good approximation of the real phenomenon in such a case. So, we get no fair relationship to predict the Preston phenomenon over this threshold. The effects of growth on life expectancy are significantly smaller than in poorer countries, and it would not be worthwhile to undertake the lengthy research process involved to assess such small effects. More importantly, it is likely that in richer countries, the effect of income on health is dwarfed by the effect of inequalities (Wilkinson and Pickett 2010). It therefore would be unethical to calculate the effects of economic growth in rich countries without considering the effects of changes in inequalities too.

3.3.2 Condition 2: significant power

The relationship (2) is calculated from data gathered at the macro state level. All of the calculations of future GDP and LEX are made at the state level. At this stage, however, the researcher must attribute a given part of health improvement to the sector being assessed. We have suggested performing this attribution according to the local added value created by sector. Consequently, as a measure of precaution, the Preston pathway only should be applied to sectors with a certain weight in the economy, whether in terms of contribution to real gross domestic product (percentage of direct and indirect added value) or of influence and lobbying. Gjølberg (2009) states that a production activity, representing about 1 % of national income, inevitably acts strongly on its immediate environment but also at the national level (through tax contributions in particular). The share of national income is a standard economic factor, but real economic power is measured at the level of bargaining power influence (the measure remains to be determined from the relevant literature). This level of influence will determine the possibility of real impact on the health status of populations (acting on peoples' living conditions, institutions and systems). If this condition is not met, it is unlikely that there will be a domino effect on other economic sectors.

3.3.3 Condition 3: duration of activity and growth rate

Based on the Easterly's work (1999) relating to the time needed before growth causes changes in quality of life, one should determine a minimum period of activity to claim that the economic activity under scrutiny has an effect. Pritchett and Viarengo (2010) defined the minimum duration of activity to obtain an effect upon potential LEX as a function of the average growth rate of the period, and of the level of the initial LEX. We based our proposition on the dynamic panel analysis and the impulse response method as displayed in the supplementary material. For the same sample of

countries as for setting relationship (2), we highlighted that *the minimum time lag is 4 years* for all countries in average. The demonstration is given in the supplementary material.

3.3.4 Condition 4: distribution of added value

In some cases, the added value generated is captured by people abroad, or by a handful of people within the country. The positive effect on population health works only if the wealth generated is spread through the other economic sectors in the country through a domino effect. The added value created must actually benefit national economic development. As individual income matters, it is necessary to get a minimum distribution of added value in terms of direct salaries. If the payroll (wages plus payroll taxes) exceeds 60 % of direct added value, it is proven that the sector contributes to the improved health status of populations. According to the report of Cotis (2009), the share of payroll for agriculture in France was 69 %. For comparison, in industry and commerce, these shares were respectively 62 and 63 %. Given the contextual differences between France and the countries eligible here, a minimum of 60 % is acceptable. Beyond wages, other components directly benefit local people such as social spending (access to education, health, etc.), additional expenses (e.g. transportation), purchases to local suppliers and, above all, spending from the workers' households. Many practitioners consider that distribution of 25 % of the *local added value* to local population entails significant and positive impacts, especially on poverty reduction (Ashley 2006; Mitchell and Faal 2007; Mitchell and Phuc 2007). If this condition is not met, the domino effect through economic sectors cannot take place. So, we selected the twin thresholds of 60 % minimum of *direct* added value distributed through payroll, and 25 % minimum of the *local* added value.

3.4 For what kind of product chain and what question?

The Preston pathway can be useful to assess change in potential LEX caused by the functioning of many product chains, but not all. As discussed in the preceding sections, four conditions must be met. First, the relationship addresses only the parts of the product chain which are embedded within "poor" countries. Second, it deals only with industries who contribute significantly to the creation of wealth in the country, and third, the industry must have done so for quite a long time. The fourth condition is that a large part of the added value is attributed through wages. Moreover, accounting data must be available and clearly assigned to the targeted product. If there are several product chains in the same company under scrutiny, it may be difficult to disentangle the necessary data.

The kinds of product chains whose functioning may be assessed by the Preston pathway are typically industries that have been or are planning to be established for a long time in developing countries. They often are devoted to exports (fruits, vegetables, mining, high technology…) and involve thousands of workers around the same product lines. Such an industry may be concentrated in one large company, or may be structured by thousands of small organisations (farms, craft workshops).

The Preston pathway may be used to answer the following kinds of questions: what are the social impacts of the operation of this product chain in country A versus country B? Or what are the social impacts of different scenarios (C and D) in the same country?

4 An example of application to a banana industry in Cameroon

4.1 Context

We analysed the banana industry in Cameroon, where "dessert bananas" are, after timber and excluding petroleum, the second largest export of the country in volume and the third in value (Loeillet et al. 2009, p. 29). The function provided by the life cycle under scrutiny is the delivery of 200,000 t of dessert bananas to the port, ready to be exported towards European markets, each year and over 20 years. The functional unit we chose is the 200,000 t of bananas exported from the port annually. We assessed only one part of the life cycle: it is a well to gate assessment, between banana plantations and the port. We studied company B, a major actor in Cameroon's banana sector. This company manages the cultivation, processing and transport of bananas, thus controlling a large part of the life cycle. We obtained all of the accounting data from this company to make calculations.

4.2 Compliance with the conditions of application of the pathway

All of the conditions to implement the Preston pathway were present. First, the activity is located in a poor country. For the past 20 years, gross domestic product per capita in PPP has not exceeded $2,100; it was $1,997 in 2009 (World Bank). Secondly, this company has a significant power in the national economy. The local value added[4] of the

[4] Local value added includes the direct (of the company) and indirect (generated by the inputs and suppliers) primary value added and the secondary value added (related to the allocation of income). This value added is different than accounting value added because it includes only cash flows that remain in the country and not those that are exported (unless they generate effects at local level).

company represented 0.53 % of the national income in 2009 (excluding hydrocarbons). It is relatively important compared to the average contribution of others branches of the economy (average, 1.84 %).[5] Third, company B was established in Cameroon in 1989. Since its installation, the business has grown steadily, with a regular annual growth rate of 8 % (FAO data[6]). We can expect that this will continue in the same way for the next 20 years. The likely duration of activity of company B is sufficient to claim that it will participate in the changes in potential LEX. Finally, in 2009, wages and social spending accounted for 60 % of the direct added value of the company. Of the local value added generated by the banana industry, 25 % was distributed directly to local people (in wages and social spending).

4.3 Application of the pathway over the next 20 years

Real LEX at birth in 1950 was 37.85 years. It increased until 1989 reaching 55.14 years and then declined for nearly 15 years (50.62 years). Since 2005, real LEX has increased again (51.39 years in 2009). Several factors may explain these trends. First, it is clear that the HIV epidemic has impacted greatly the overall health of the population,[7] Cameroon being the 11th most affected country in terms of deaths (37,000 deaths in 2009; UNAIDS 2010). Moreover, the devaluation of the CFA franc in 1994, although it had the effect of boosting competitiveness, strongly affected the purchasing power of its population, which became insufficient to improve the material conditions of households and therefore to improve the necessary health conditions (hygiene, access to care, etc.).

The past 20 years in Cameroon have been marked by numerous crises involving armed conflicts, famine and natural disasters that preclude the application of the Preston pathway as they do not meet the required conditions.

We therefore focus on the period 2010–2030. Given that company B has been constantly involved in the national economy since it was set up, and assuming this activity lasts over time, we hypothesize that company B will have an effect on the change in potential LEX over this period. The duration of activity also is long enough to take into account the lag between effects on GDP change and those on potential LEX change.

[5] There are 44 branches in the input–output matrix provided by the National Institute of Statistics of Cameroon. Each of these branches comprises hundreds or thousands of companies.

[6] See http://faostat.fao.org

[7] It was shown that in the most affected countries, HIV was responsible for a decline in LEX of 10 years (UNPD 2003).

4.4 Contribution of company B to the change in potential LEX

We hypothesize that *the contribution of company B to the change in potential LEX is in proportion to its contribution to the change in national income*. We therefore must calculate both the likely change in LEX in Cameroon for the next 20 years (step 1) and the contribution of company B to the change in gross domestic product per capita for the next 20 years (step 2). The calculation of the contribution of company B to the change in potential LEX thus is made in two steps, summed up in Fig. 2:

- Step 1: calculation of the *change in potential LEX in Cameroon*, estimated by our recalculated relationship (2).
- Step 2: calculation of the proportion between the local value added generated by company B (between 2010 and 2030) and the overall change in national absolute gross domestic product (PPP, in constant 2005 US dollars) in Cameroon over the same period. This proportion allows us to deduce the contribution of company B to the change in national income.

Step 1: First, prevision of potential LEX from the recalculated relationship (2), for the period 2010–2030, is based on the following assumptions:

1. We estimated the future national gross domestic product in PPP (constant 2005 US dollars) for each year, by using the average annual growth rate over the period 1995–2009,[8] which is 3.81 %;
2. We estimated the future national population for each year by using the growth rate of the immediately antecedent year and taking into account the slowdown in population growth[9];
3. We estimated the future gross domestic product per capita in year n by the ratio between the national income in PPP in year n and the level of national population in year n.[10] This was done for all years between 2010 and 2030.

[8] We choose the period 1995–2009 because it is only since this period that the country has experienced economic development without the occurrence of major disruptive events that could bias the analysis.

[9] Given the demographic transition, the population growth rate is positive but diminishes gradually (Pinson 2009). Thus, we calculated a decrease in the population growth rate of 0.04 % per year over the period 1989–2009. We apply it to future population growth.

[10] We compared these results with the future gross domestic product per capita calculated from the Gapminder data, estimated for each year using the average annual growth rate over the period 1995–2009 (1.48 %). Both provide comparable results, but we preferred using data resulting from the two calculations steps (1 and 2), due to the lack of transparency of the calculations made by Gapminder.

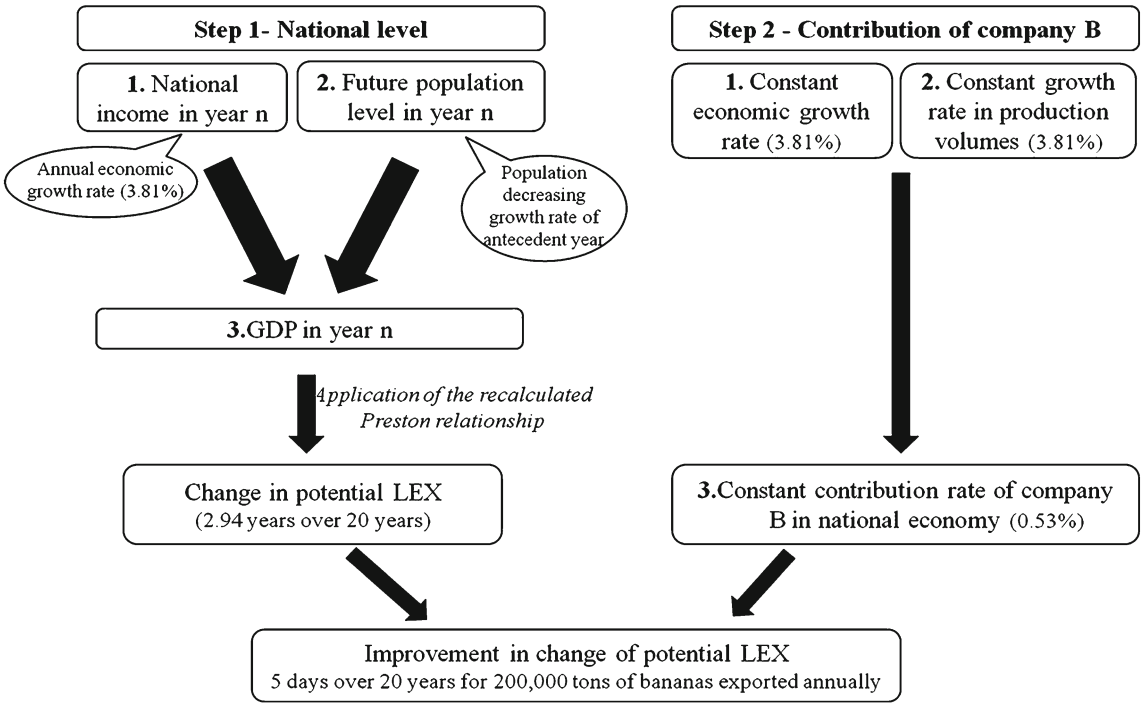

Fig. 2 Schematic representation for the calculation of the improvement in change of potential LEX

We set the figures stemming from the previous assumptions into the relationship (2) to determine the potential LEX for the period 2010–2030.

Between 2009 and 2030, *potential LEX of Cameroon is expected to increase by 2.94 years*, from 53.08 to 55.89 years, predicted values given by the relationship (2).

Step 2: Second, the calculation of the contribution of company B is based on the following assumptions:

1. We considered a constant economic growth rate of around 3.81 %, based on the average annual growth rate over the period 1995–2009.
2. Based on the developments planned by company B, we assumed a growth rate in production volumes of 3.81 % per year. Between 2010 and 2030, company B thus is expected to export 4 million tons of bananas, or an average annual production volume of 200,000 t (hence the value of the functional unit).
3. Given the similar economic and production growth rates, we kept constant the rate of contribution of the local value added generated by the activity to the national income (0.53 %). Between 2010 and 2030, company B is expected to generate $6.7 billion.

Based on this third assumption, company B would contribute in the same proportion to the change in LEX over the same period. Therefore, it would contribute to increasing the potential LEX by *5 days over the next 20 years for the entire population of Cameroon* (based on the calculation 0.53 %× 2.94 years=0.015 years or 0.18 months). This gain of *5 days*

Table 2 Mitigated and remaining uncertainties when using outputs from the Preston pathway, for three kinds of comparison

Kind of comparison (with country A, company X)	Comparing mitigates uncertainties about	Remaining uncertainties about
a) Same country A, same company X, variant scenario	GDP and LEX data for A Relationship itself Accounts of nation A	Data provided by X
b) Same country A, another company Y in the same sector	GDP and LEX data for A Relationship itself Accounts of nation A	Data provided by A, by Y
c) Another country B, same sector company Z	Relationship itself	GDP and LEX data for countries A, B Accounts of nation A, B Data provided by A, by Z

over 20 years is derived from the 200,000 t of bananas exported annually.

5 Discussion and conclusions

We shall discuss here the limits of this approach and future research needs. The first paragraph focuses on the limits linked to the Preston pathway itself, and on ways to overcome these difficulties. Some specific pitfalls stem from downscaling between macro and micro levels. We will conclude with a discussion of future research issues raised by our work.

5.1 Overcoming the limits inherent in the Preston relationship

The Preston pathway tells us something about one of the most important social impacts, *changes in human health*. The recalculated, panel-based relationship (2) may be used under appropriate conditions to explain or predict the change in potential LEX generated by a change in economic activity. The resulting Preston pathway is an attempt to contribute to a framework for social LCA, consistent with the LCA philosophy developed thus far in environmental sciences, that has been called for by several authors (Weidema 2006; Jørgensen et al. 2010b). However, some issues deserve to be discussed more deeply, and some others have not yet been addressed. There may be several sources of error in the approach proposed in this article, leading to mistakes when calculating change in potential LEX. We first shall examine these sources of error and then suggest means to overcome them as much as possible.

– An obvious source of uncertainty comes from the lack of precision of some data sources of international figures. The only solution is to choose, as we did, the most robust available source. Limits inherent to the accuracy of the relationship are trickier. If everything could be converted into figures, the relationship (2) would be established between levels of individual real income and real health. Taking GDP as an approximation for the sum of individual real incomes, and LEX as an approximation for the result of the sum of individual health, obviously introduces errors. The first approximation does not take into account informal income or unearned income, which can be very important. In our case, it does not sufficiently reflect the informal economy, which is particularly widespread in developing countries. Gross domestic product therefore is controversial. Similarly, LEX is the best available global proxy for health when data on disease are not available (see Section 2.1.1), but it is not exactly health.

Even using real income and health, the link between both variables is not direct. It depends on the situation and time lag between income growth and the realization of improvement in health, through multiple meanders and loops of individual behaviours, public policies and civil society (NGOs), in terms of growth of revenue, education and health expenditures, the effectiveness of these expenditures… to mention only a few. At the world level (cross section), it has been proved (Filmer and Pritchett 1999; Pritchett and Viarengo 2010) that introducing three supplementary variables (female education, religious background and HIV epidemic) alongside GDP leads to the highest possible correlation (around 80 %) with LEX that one can expect from real data. We do not use this "augmented" Preston relationship because the data required usually are unavailable. We adopt a parsimony approach since we obtained satisfactory results with a "simple" model. All these drawbacks entail more uncertainties than those described by the statistical uncertainties around the result provided by the relationship (2). Like Schmidt and Weidema (2009) when comparing attributional and consequential modeling, we prefer a more correct (accurate) but imprecise model than a precisely incorrect (inaccurate) model, which for instance would not take into account the effects of economic activity on population health in poor countries. The first condition for use (poor country) is an attempt to use the relationship where it is accurate, as far as possible. This is not, however, enough. We strongly urge that results be interpreted carefully by relying in particular on the following: a *comparative perspective* and *multi-criteria analysis*.

It is meaningless to produce results per se without a *comparative perspective*. This is not new in LCA because "to compare variants with the same functional unit is a recommendation known to enhance the validity of results obtained in LCA Environmental" (Owens 1997). The change in potential LEX per 200,000 t of bananas exported annually therefore must be compared with a) other variant scenarios in the same country A and company X (e.g. if doubling production), b) changes in potential LEX of another banana industry Y in the same country A and c) changes in potential LEX of another banana industry Z in another country B (i.e. Ghana, Ecuador). Each comparison involves specific uncertainties, and "neutralizes" or at least mitigates others (because the error will likely be the same for both compared cases). Table 2 presents the three cases.

Multi-criteria analysis offers three advantages. The first is obvious when dealing with overall social assessment. General population health is not the only social impact category. It is worth developing impact pathways for other impact categories (e.g. see Weidema 2006) and for other stakeholders (e.g. specifically workers). Highlighting the

potential "impacts[11] transfer" phenomenon is the second advantage of multi-criteria analysis. We need at least two pathways to observe it. The third advantage is the opportunity to carry out triangulation[12] (Eden and Spender 1998), when the supplementary criteria also are applicable to the population health impact category. By building other pathways about variables influencing population health (e.g. income inequities), we acknowledge the role of other effects than the level of income, and we assess the changes in health.

5.2 Overcoming the limits linked with downscaling from macro to micro

When one transfers a general relationship (at the national scale) to the level of a sector or company, one may find that the national level relationship does not fit the level below. We hypothesize that the rate of contribution of the sector/company to the change in GDP reflects the rate of its contribution to the change in LEX. It therefore is especially important to check that proportionality is fair. Drawing from economics literature on development, we identified conditions (1), (2), (3) and (4) which provide the best guarantee that this be the case. The conditions are not infallible, but the best we have to date, given our present state of knowledge.

Other sources of uncertainty lie in the quality of the data available at the level of a company, sector and nation. Moreover, the calculation of local added value can overestimate the level of the secondary added value because of the "effects and multiplier methods" (Garrabé 2010, p. 32) in use.

When using the Preston pathway for prevision, we add another source of error through accuracy of the forecasts. Even when rooted in past trends, assumptions made about the future (economic growth rate, changes in company B and population growth) are only bets. They have the scientific status of a hypothesis.

To overcome most of the limits linked with downscaling, it would be better to set up the relationship suggested by the results of the impulse response method (see supplementary material), including lagged variables in the model. This formalized relationship would allow to calculate the change in potential LEX resulting from a shock (change) in GDP occurring more than 4 years before. Thus, the conditions for use would be less restrictive in the sense that we could calculate the impact of a change at micro-level directly. We are currently addressing this question.

5.3 Future research needs

As previously mentioned, we are searching to build other pathways, especially ones dealing with the health impact category, either at the population level, or for some specific stakeholders. However, work remains to be done to fine-tune the Preston pathway.

With respect to the four application conditions proposed, suggestions for other conditions and thresholds are welcome. In particular, we seek improvements on calculating the level of influence of a company (condition 2), and for the condition 3. The issue of time deserves in-depth consideration. If the local added value of the sector/company is not stable over time, which descriptive statistic is most relevant (e.g. average, minimum)? Similarly, how may unsteady growth be taken into account?

All changes in LEX do not have the same meaning. Expressing LEX in Quality-Adjusted Life Years (QALYs) would allow both the *length* and *quality* of life to be taken into account simultaneously. However, some scientific questions still need to be explored (Moatti et al. 1995) concerning the relationship between QALYs and "preferences" (concept at the root of the state health assessment by people, leading to QALYs), or even concerning the quality of life assessment. However, such developments would actually lead to an endpoint impact (Udo de Haes and Lindeijer 2002: Jolliet et al. 2004). Formalizing calculated outputs in QALYs is a further step in the building of the pathway.

We have tried to explore the Preston empirical relationship in order to build an operational pathway contributing to impact assessment in social LCA. We have presented the Preston curve and discussed controversial scientific debates regarding its interpretation. We have performed panel-based calculations to prove that the relationship (2) applies to a given country alone. We have discussed the conditions for use to mitigate errors when the pathway is implemented in a given sector or company. We have implemented it on one relevant case in Cameroon. However, the outputs cannot be used in isolation. Comparative and multi-criteria analyses are essential to provide meaningful interpretation. The Preston pathway currently thus may be viewed as an operational but not infallible tool. Numerous scientific questions remain to be explored. More work is needed to build other pathways and fine-tune this one. All criticism is welcome to improve the correct implementation of the Preston pathway.

[11] Impact transfer is the phenomenon such as when comparing two variant scenarios, the impact X is improved, but to the detriment of the impact Y.

[12] Triangulation is a scientific method, well known in social sciences, to get insight about the same issue from different sources and by different ways.

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